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RESEARCH ARTICLES

Comparative evaluation of physico-chemical response of tomato varieties under hydroponic technique vs soil cultivation in natural ventilated greenhouse at trans-Himalayan India

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Abstract

The present study investigated the growth response, yield and nutritional quality of tomato varieties viz. *Roma, Tolstoi and Russian yellow* grown in circulated nutrient film technique (NFT) hydroponic systems and soil condition at high altitude condition. Both the experiments were carried out in double layer polycarbonate greenhouse condition with open window to maintain favorable atmosphere. Tomato varieties under NFT system exhibited significant improvement in plant height (cm), number of leaf and fruit/plant, fruit fresh weight (g), fruit diameter (mm) and yield compared to soil condition. It was found that 70–80% water was saved in NFT systems compared to soil condition during tomato production. Mineral nutrient contents like Cu, Mn, Mg, Zn and Fe in fresh fruit of tomato grown in hydroponic systems were found higher than soil condition. Total soluble solid (Brix) was found similar in hydroponics and soil condition. Anthocyanin and chlorophyll in tomato leaf were found high in NFT compared to soil condition. From the various aspect of comparative study it was found that NFT system of hydroponics performed better than field grown tomato with respect to shorter harvesting period, higher productivity and quality production of tomato varieties. Since NFT system requires less space and water, this system may be promoted in extreme climatic condition and urban area as an alternative to conventional farming. This research surely opens the avenue of hydroponics technique to increase the income of farmers to promote sustainable development.

Keywords High altitude · Mineral nutrient · NFT hydroponics system · Tomato · TSS

Introduction

Leh-Ladakh is high altitude cold desert region of India, has very harsh climatic condition, short agriculture season and land locked for about 6 months during winter months. The high radiation level, low humidity and only one cropping season in a year (May–October) are typical characteristics of this region. In order to meet the basic human requirements, hydroponic technique has been implemented for getting fresh tomatoes in extreme high-altitude condition. However, this region possesses major challenges in fresh vegetables production throughout the year. The major problem

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of tomato cultivation in cold desert geographical area is that the fruit is not mature at harvest time due to low temperature. Thus, obtaining quality productions is one of the main challenges for tomato crop.

Off all vegetables, tomato is qualitatively and quantitatively one of the most important components of Mediterranean diet. Tomato is widely grown vegetables in the world are mainly consumed as raw or cooked due to their desirable nutritional properties. More than 80% of tomatoes grown are consumed in the form of processed products such as juice, soup and ketchup or paste (Kaur et al. 2008). In terms of nutritional composition tomato contains moisture (95%), carbohydrates (3%), protein (1.2%), lipids (1%), minerals (Ca, Mg, P, K, Mn, Na and Zn) and vitamins (A, C, thiamine, riboflavin and vitamin B) (Perveen et al. 2015; Melfi et al. 2018; Mohammed et al. 2020). The consumption of tomatoes has been associated with the prevention of cardiovascular diseases, maintenance of bone health and several types of cancer such as colon, rectal, prostate and stomach cancer (Cheng et al. 2017). Lycopene, the principal carotenoid of tomato has been linked with several health benefits and strongly associated with prevention of chronic degenerative diseases (Agarwal and Rao 2000; Cheng et al. 2019). These compounds may play an important role in inhibiting reactive oxygen species through free-radical scavenging, metal chelation, inhibition of cellular proliferation, modulation of enzymatic activity and signal transduction pathways to protect several diseases (Crozier et al. 2009). The phenolic and flavonoid present in tomato also protect skin form bright sunlight. Therefore, tomato product is important for high altitude cold desert region.

In Leh-Ladakh, agriculture faces major challenges due to lack of adequate water resources for irrigation. With the hydroponic techniques, most of the complexities and interference induced by soil and environmental factors are avoided and better control of the experiment can be achieved. Hydroponics is the technique of growing plants in soil-less condition with their roots immersed in nutrient solution. Currently hydroponic cultivation is gaining popularity all over the world because of efficient utilization of natural resources especially in areas where soil and water is limiting factor for plant growth, helps to face challenges of climate change and quality food production. The enhancement in plant density promoted by multi-storey hydroponics cropping systems increase fresh fruit mass and yield per area (Sharma et al. 2018). In NFT hydroponics system**,** the roots of plants are placed on the shallow circulating nutrient water layer (Fig. 1). The roots of the plant absorb nutrients and oxygen from nutrient water that flows continuously using a pump. The amount and type of hydroponics nutrients supplied to tomato can influence not only its yield but also its nutrient content. Nutrients such as N, P, K, Ca, Mg, and S, are needed in large amounts for normal growth and reproduction of tomato while Fe, Cu, Zn, Mn, B, Mo and Cl are required in small amounts in hydroponics as well as soil cultivation (Sainju et al. 2003). The growth media is fortified with nutrients for the production of tomato in hydroponic system. The mineral composition of tomato depends on the nutrients taken from the growth medium, and the adequate amount of nutrients should be necessary for the better production and nutrient content of tomatoes grown in NFT system (Sharma et al. 2018). Therefore, the hydroponics technique for tomato cultivation influences yield and quality. Henceforth, the present study was undertaken to evaluate the growth, yield and nutritional quality of tomato grown in hydroponics systems and compared them with soil grown tomato.

Materials and methods

The present experiment on comparative evaluation of tomato production in hydroponic Techniques Vs soil cultivation were conducted during summer season of 2019 at Vegetable Research Unit, Defence Institute of High-Altitude Research, DRDO, Leh-Ladakh. The experiment was conducted under

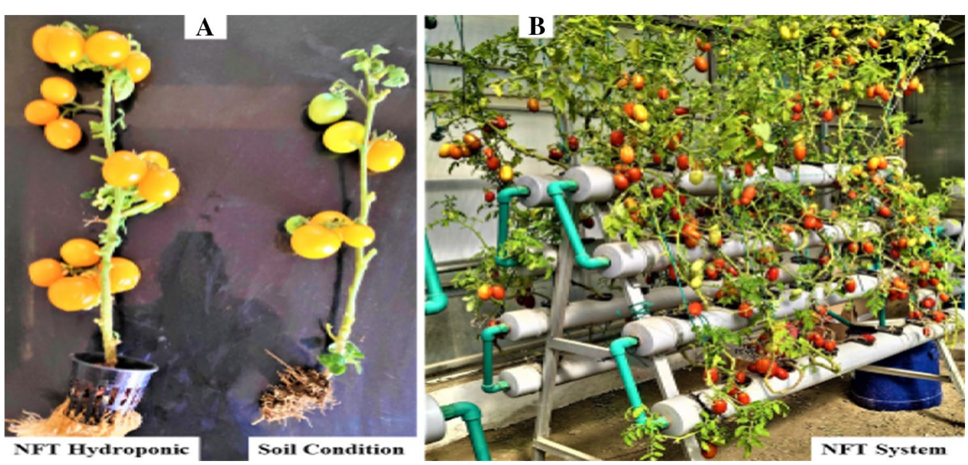

Fig. 1 **a** *Russian yellow* tomato grown in NFT system and soil condition. **b** *Roma* tomato grown in NFT hydroponic System

double layered polycarbonate green house, with permanent open window on both sides for natural ventilation i.e. without any artificial fan for air flow. The ground of the greenhouse was uniform and levelled. The monthly weather data of air temperature and relative humidity during the experimental period of tomato production are presented in Fig. 2.

NFT hydroponic system

The NFT hydroponic structures were specially designed for vegetable cultivation. Vertical NFT unit was pyramid shaped with four tiers having dimension (L × W × H) of (160 × 90 × 150) cm with a reservoir of 60 L capacity. One vertical NFT system had 60 positions for net pots and in each net pot one seedling was transplanted. In one meter square ground cover, 32 plants were accommodated in the 4 tier vertical NFT system. Net pod spacing or plant to plant spacing was maintained at 22.8 cm. Water was circulated through a submerged pump in the reservoir. In circulated system nutrient solution is pumped from the reservoir, circulated from upper layer to lower layer and excess solution collected, replenished and reused in these methods. Crop water requirements are a function of crop characteristics, management and environmental demands. Water requirements in entire tomato production cycle was analysed through amount of water applied each time in reservoir up to harvesting time as well as in field conditions. It's expressed in kg yield production per liter (Kratky 2003).

Preparation of hydroponics solution

Hoagland nutrient solution (General Hydroponics flora series, USA) was used for hydroponic cultivation of tomato. Hoagland nutrients solution having standard composition with N 210 ppm, K 235 ppm, Ca 200–160 ppm, P 31 ppm, S 64 ppm, Cl 0.14–0.65 ppm, Na 0.023–1.2 ppm, Mg 48.6 ppm, B 0.11–0.5 ppm, Mn 0.11–0.5 ppm, Zn 0.023–0.05 ppm, Cu 0.014–0.02 ppm, Mo 0.018–0.011 ppm, Fe 2.9–5 ppm was used. Up to flowering stage, 2.5 ml of nutrient solution was mixed with 10 L of water whereas 5.0 ml of nutrient solution was mixed with 10 L of water and used it during fruiting stage. The pH and EC values of the hydroponics nutrient solution were measured routinely using a pH and EC meter (HACH, USA). Trejo-Téllez and Gómez-Merino (2012) reported that the pH range of hydroponics solution varies between 6.0 and 6.5 for optimum growth of plant. The NaOH and HCl were added to maintain the pH of nutrient solution between 6.0 and 6.5.

Crop management

Hydroponic system (circulated NFT) and soil condition were evaluated for production of tomato varieties (viz., Indeterminate-*Tolstoi and* determinate- *Roma and Russian yellow*). The tomato seedlings were grown in a mixture of cocopeat, vermiculite and perlite (5:2:1) media in nursery inside green house. These seedlings were ready to transplant in 25 days and uniform seedlings were transplanted in different hydroponic system and soil condition. The seedlings were placed into net pots in growing channels in circulated NFT system. The net pots were filled with clay balls for supporting seedlings. The reservoir capacity is 60 L in NFT system. Plants take up nutrient solution continuously, hence fresh nutrient solution was added approximately every 12–15 days interval when the reservoir solution level was down to 8–10 L. pH and electrical conductivity (EC) of the nutrient solution

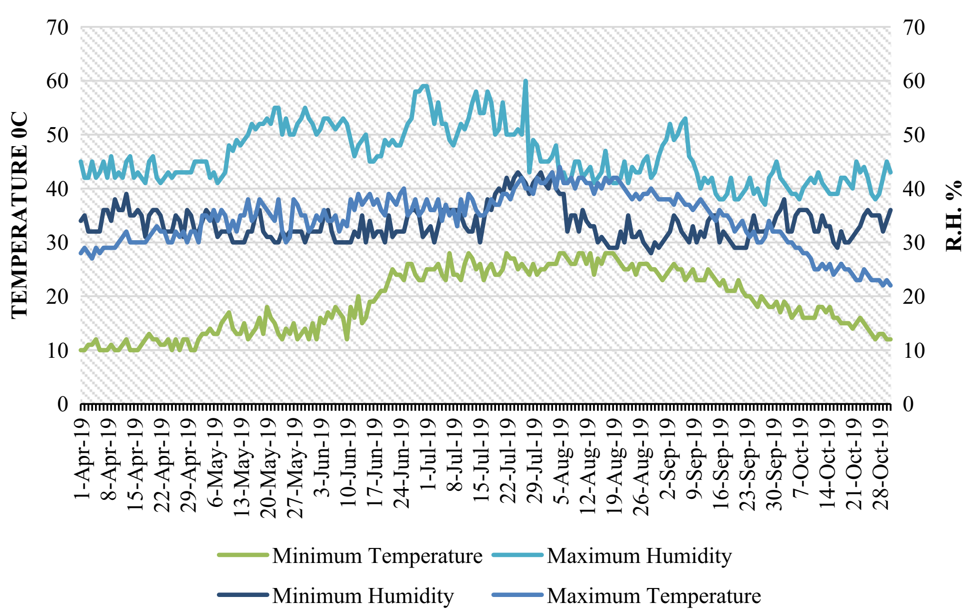

Fig. 2 Relative humidity (%) and temperature (°C) inside greenhouse between April and October 2019 during the experimental period in Ladakh. Different colour line represents maximum and minimum RH and Temperature

was maintained at 6.2–6.5 and 1.8–2.4 dSm^{-1} respectively. Tomato plants were harvested after 12–14 weeks after transplantation.

Measurements of growth, yield and fruit quality parameter

Three randomly selected plants were taken from each experimental site (hydroponic and soil condition) for measuring plant growth parameters. At the time of flowering, eighteen plants were tagged and the total number of fruits per plant was counted from each system as well as soil condition. Fruit yield was expressed in terms of kg m^{-2}. Polar and equatorial fruit diameter of tomato was measured with Vernier Calipers.

Measurement of chlorophyll, TSS and anthocyanin

Chlorophyll and anthocyanin content in leaf were determined by portable chlorophyll and anthocyanin meter respectively (CCM-200 plus and ACM-200 plus, ADC Bioscientific, UK). Total soluble solid (TSS) is an index of soluble solids concentration in fruit. Homogenized ground tomato tissues were filtered through filter paper Whatman No. 1 using vacuum and the total soluble solid were determined by a digital refractometer (ATAGO, USA) and expressed in °Brix.

Nutrients analysis of tomato cultivars

The mineral content of the tomato samples was determined using the AOAC (1990) methods. Magnesium (Mg), Manganese (Mn), Iron (Fe), Copper (Cu) and Zinc (Zn) were determined by AAS (Make: Analytik Jena; Model: ZEEnit 700P) using standard solution (Sigma Aldrich) of respective elements. Briefly, about 200 mg of sample was first digested in microwave digestion system (Make: Analytic Jena; Model: Topwave) with 8 ml of di-acid mixture (6.0 ml nitric acid and 2.0 ml HCl). The digestion flask containing the sample and the digestion acid mixture was heated until a clear digest was obtained. The digested samples were later diluted with distilled water to 50 ml mark. After obtaining the digest, aliquots of the clear digest were used for atomic absorption spectrophotometry using filters that matched the different elements. The concentration of minerals in fresh fruit was expressed in mg per 100 g.

Statistical analysis

All experimental data were expressed as mean ± standard deviation using statistical analysis with SPSS 22 (SPSS Corporation, Chicago, Illinois, USA) and MS excel 2019. Differences between mean values were evaluated using one way analysis of variance (ANOVA). The differences were compared using the Duncan's test with a significance level of 5%.

Result and discussion

Plant growth and yield attributes of tomato varieties

The tomato varieties grown under hydroponic NFT systems compared to soil condition on growth, morphology and yield attributing characters (plant height, number of leaf & fruits, weight of fruits & diameter, water required and yield) of tomato varieties is presented in Table 1. The tomato varieties exhibited significant differences in above attributes grown in NFT system compared to soil condition. It was observed that the plant height of *Tolstoi* variety grown in NFT (107.30 ± 1.75 cm) as well as soil condition (81.90 ± 2.35 cm) was found maximum while minimum plant height was found in *R.yellow* variety in both conditions (NFT system 30.32 ± 0.62 cm & Soil condition (28.14 ± 0.67 cm). The highest number of leaves per plant was recorded in *Tolstoi* gown circulated NFT system (28.81 ± 1.51) and the lowest number of leaves per plant was recorded in *R. yellow* (17.19 ± 0.7) grown in soil control condition. The number of fruits per plant in *Tolstoi* grown in NFT system (24.20 ± 0.85) was significantly higher ($P < 0.05$) than *R. yellow* grown in soil condition (8.0 ± 1.0). Cardoso et al. (2018) reported that higher plant height and number of leaves increase fruit production per plant in hydroponic NFT system compared soil condition. It might be possible because higher number of leaves causes higher photosynthetic reaction leading to more photosynthetic product. *Roma* variety grown in NFT circulated system (54.56 ± 1.65 g) exhibited maximum values for fruit weight followed by *R. yellow* variety grown in NFT circulated system (48.69 ± 1.10 g) and lowest value of *Tolstoi* in soil condition (42.03 ± 1.36 g) at $P < 0.05$. *Roma* grown in NFT system showed significant ($P < 0.05$) difference in fruit weight. The fruit diameter was significantly ($P < 0.05$) higher in *Tolstoi* (39.34 ± 0.81 cm) cultivated in circulated NFT system and minimum recorded in variety *R. yellow* (25.17 ± 0.7 cm) cultivated in soil control. It was observed that tomato varieties grown in NFT system showed significantly better growth characters than respective soil grown conditions. It was also observed that maturity period of hydroponic tomato varieties was significantly shorter compared to soil grown tomato.

The maturity period was started in 110 days in circulated NFT system while in soil condition it was recorded in 125 days. The finding of the present study is in line with similar with Kratky et al. (2005) who reported

Table 1 Comparative evaluation of growth and yield attributing characters of tomato varieties grown in NFT hydroponic systems and soil condition

Growing condition	Plant Height (cm)	No. of leaf plant^{-1}	No. of fruit plant^{-1}	Fresh fruit weight (g)	Fruit Diameter (mm)	Water consumption (liter Kg^{-1})	Yield (kg m^{-2})
NFT VERTICAL C. Roma	80.34 ± 1.15^{c}	24.33 ± 0.95^{d}	13.91 ± 0.62^{c}	54.56 ± 1.65^{d}	37.92 ± 1.23^{d}	64.11 ± 1.53^{a}	24.31 ± 1.78^{d}
SOIL CONTROL Roma	57.59 ± 0.75^{b}	15.24 ± 1.30^{a}	9.51 ± 0.87^{ab}	46.17 ± 0.95^{b}	30.81 ± 1.7^{b}	534.84 ± 14.86^{c}	4.38 ± 0.31^{a}
NFT VERTICAL C. Tolstoi	107.30 ± 1.75^{d}	28.81 ± 1.51^{e}	24.20 ± 0.85^{e}	44.23 ± 0.81^{ab}	39.34 ± 0.81^{d}	62.97 ± 2.07^{a}	34.32 ± 1.83^{e}
SOIL CONTROL Tolstoi	81.90 ± 2.35^{c}	20.30 ± 0.70^{c}	20.43 ± 0.87^{d}	42.03 ± 1.36^{a}	35.62 ± 1.17^{c}	537.61 ± 6.08^{c}	7.73 ± 0.37^{b}
NFT VERTICAL C. R. yellow	30.32 ± 0.62^{a}	18.55 ± 1.16^{bc}	10.38 ± 0.71^{b}	48.69 ± 1.10^{c}	29.57 ± 0.65^{b}	51.66 ± 3.50^{a}	16.19 ± 1.46^{c}
SOIL CONTROL R. yellow	28.14 ± 0.67^{a}	17.19 ± 0.70^{ab}	8.00 ± 1.00^{a}	42.11 ± 1.21^{a}	25.17 ± 0.70^{a}	335.34 ± 4.88^{b}	3.36 ± 0.32^{a}

Data were shown in mean ± standard deviation (n = 9)

The values with the different letter within same column are statistically significant by Duncan's test at $p \leq 0.05$

early maturity period for tomato under hydroponic system. The production (kg m^{-2}) of *Tolstoi* and *Roma* grown in NFT condition was recorded 34.32 ± 1.83 and 24.31 ± 1.78 kg m^{-2}, respectively, while water requirement was almost same for both the varieties in NFT condition (Table 1). The variety *R. yellow* grown in soil condition had lower production (3.36 ± 0.32 kg m^{-2}). In vertical NFT system, 32 plants were accommodated per square meter ground cover whereas for soil cultivation, it was 09 plants m^{-2}. The water consumption (litre/kg yield) was significantly higher in soil cultivated *Tolstoi* (537.61 ± 6.08), *Roma* (534.84 ± 14.86) and *Russian Yellow* (335.34 ± 4.48) whereas for hydroponically grown tomato it was significantly very less and only 62.97 ± 2.07, 64.11 ± 1.53, and 51.66 ± 3.50 for *Tolstoi, Roma* and *Russian Yellow* respectively which is shown in Fig. 3. Cardoso et al. (2018) and several other also reported very less water requirement in hydroponic conditions. It is due to fact that in field condition, irrigated water is lost by means of various factors such as leaching, evapotranspiration etc. dos Santos et al. (2013) reported that higher yield of tomato in NFT system attributed to high plant density. In NFT system water is pumped from the reservoir, circulated from upper layer to lower layer and reused. Therefore, tomato varieties grown in NFT required very less water. The tomato production in NFT hydroponics system saved about 70–80% water with maximum yield compare to field condition which is also supported by works of Kratky (2003) and Kratky et al. (2005). Parmar et al. (2018) analysed the performance of different tomato cultivars under organic regime and they found that different tomato cultivars behaved significantly different from each other concerning various parameters

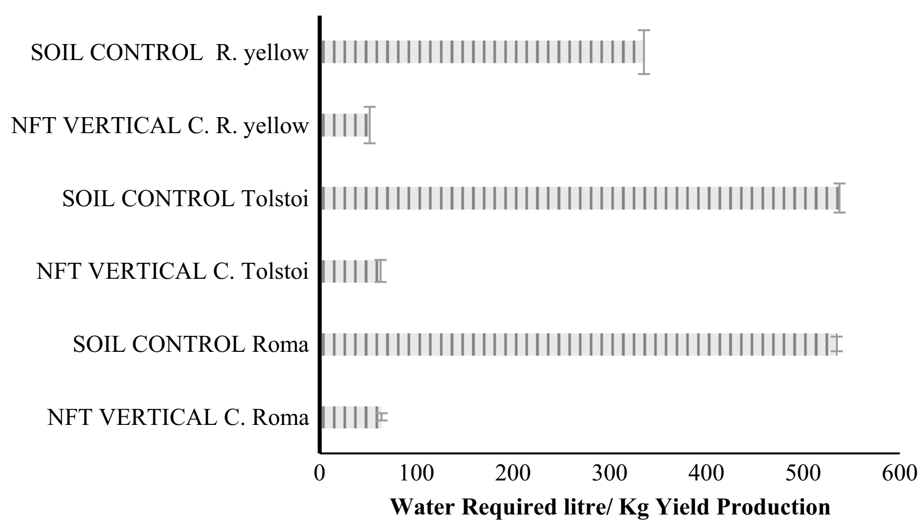

Fig. 3 Water requirement (litre kg^{-1} yield) of tomato varieties grown in NFT hydroponic system compared with soil condition in greenhouse condition. Data were shown in mean ± standard deviation (n = 9). The values with the different letter within same column are statistically significant by Duncan's test at $p \leq 0.05$

such as plant height, number of fruit/plants, yield, TSS and pigment content.

Leaf pigment contents and fruit TSS contents of tomato

Plant pigment contents and fruits TSS of tomato varieties as influenced by hydroponic growing condition and soil condition is described in Table 2. The *R. yellow* NFT circulated system exhibited significantly highest anthocyanin content (6.03 ± 0.25 ACI) followed by *R. yellow* soil cultivation (5.58 ± 0.11 ACI) and *Tolstoi* with NFT system (5.37 ± 0.21 ACI). The tomato variety *Tolstoi* in soil condition showed lowest anthocyanin content (3.90 ± 0.30 ACI). A Maximum accumulation of chlorophyll content was observed in *R. yellow* variety grown in NFT (20.93 ± 1.39) followed by soil condition (17.92 ± 1.65 CCI). The lower chlorophyll content was recorded in soil control *Tolstoi* (14.19 ± 1.12 CCI). The accumulation of chlorophyll was found significantly similar in *Roma* and *Tolstoi* grown in NFT system**.** Variations in plant pigment contents was observed across varieties as well as growing conditions (hydroponic and soil cultivation). Leaf chlorophyll content is one of the most important attributes indicating the photosynthetic capacity as it contains reaction centres that facilitate the process of photosynthesis in plants (Mao et al. 2007). The evaluation of chlorophyll content is important to understand the efficiency of plant stimuli (e.g. nutrient and water stress) and changes in chlorophyll content may be good indicators of growth and physiological status of plants (Demotes et al. 2008). Increased levels of zinc and iron in plant leaves have been reported to increase chlorophyll content in plant because, these nutrients act as a structural component of proteins and enzymes which are responsible for normal development of pigments biosynthesis (Hisamitsu et al. 2001). As the plant grows, translocation of nitrogen from leaves to the reproductive organs takes place due to senescence, hence the reduction in leaf chlorophyll content (Jeuffroyet al. 2002) was observed.

Tolstoi grown in circulated NFT system showed highest TSS content (6.77 ± 0.06 brix) followed by Roma (6.63 ± 0.06 brix) while lowest values were recorded in *R. yellow* variety with soil condition (6.03 ± 0.06 brix) and NFT (6.17 ± 0.15 brix). The TSS content varies with variety of tomato and fruit ripping stages. The average TSS content of the tomato fruits was found in the range (6.67–6.03°Brix) grown in NFT as well as soil condition which was significantly higher than reported by Seleguini et al. (2006) who evaluated TSS ranges (4.47–4.67°Brix) for tomatoes grown under greenhouse conditions. It may be explained by the fact that higher mineral nutrient content was observed in *Roma* and *Tolstoi* grown in NFT which showed higher value of TSS in *Roma* and *Tolstoi.* These results agree with those of Tariq et al. (2020) who evaluated the foliar application of micronutrients and found to increase the TSS of plum fruit, beside it also depends on the agronomic practices of plum orchards.

Mineral nutrient content (Cu, Fe, Mg, Mn, Zn and Fe) of tomato varieties

Influence of hydroponic system and field grown conditions on mineral nutrient content (Cu, Mn, Mg, Zn and Fe expressed as mg $100g^1$ fresh weight) of tomato were evaluated and how mineral contents varies with tomato varieties were also studied in the experiment and the results are presented in Table 3.

From the results it was observed that maximum Fe content (3.74 ± 0.02 mg) was recorded in *Roma* in NFT system compared to all other varieties. The Fe concentration of NFT grown *Tolstoi* (1.38 ± 0.02 mg) and *R. yellow* (1.36 ± 0.02 mg) was found almost similar but significantly higher than soil condition. Similarly, the Mg concentration of *Roma* was found significantly higher in NFT (19.42 ± 0.85 mg) and *R. yellow* (13.63 ± 0.74 mg) grown in soil condition had lower Mg concentration compared to other varieties of tomato. The Zn concentration was also found maximum in *Roma* followed by *Tolstoi* and *R.yellow* grown in NFT system while

Table 2 Variations in plant leaf pigments and fruits TSS of tomato varieties grown in NFT hydroponic systems and soil condition

Growing conditions	Anthocyanin content (ACI unit)	Chlorophyll content (CCI unit)	TSS (brix)
NFT VERTICAL C. Roma	4.76 ± 0.05[b]	16.59 ± 0.86[ab]	6.63 ± 0.06[d]
SOIL CONTROL Roma	4.18 ± 0.20[a]	15.74 ± 1.55[ab]	6.44 ± 0.05[b]
NFT VERTICAL C. Tolstoi	5.37 ± 0.21[c]	16.17 ± 1.70[ab]	6.77 ± 0.06[d]
SOIL CONTROL Tolstoi	3.90 ± 0.30[a]	14.19 ± 1.12[a]	6.50 ± 0.10[bc]
NFT VERTICAL C. R. yellow	6.03 ± 0.25[d]	20.93 ± 1.39[c]	6.17 ± 0.15[a]
SOIL CONTROL R. yellow	5.58 ± 0.11[c]	17.92 ± 1.65[b]	6.03 ± 0.06[a]

Data were shown in mean ± standard deviation (n = 9)

The values with the different letter within same column are statistically significant by Duncan's test at $p \leq 0.05$

Table 3 Comparative study of mineral nutrients contents of tomato varieties grown in hydroponic systems and soil condition

Growing conditions	Fe (mg 100 g^{-1})	Mg (mg 100 g^{-1})	Zn (mg 100 g^{-1})	Mn (mg 100 g^{-1})	Cu (mg 100 g^{-1})
NFT VERTICAL C. Roma	3.74 ± 0.02^{e}	19.42 ± 0.85^{d}	1.23 ± 0.06^{e}	0.62 ± 0.01^{d}	0.12 ± 0.01^{b}
SOIL CONTROL Roma	3.01 ± 0.04^{d}	18.42 ± 0.48^{d}	0.66 ± 0.01^{a}	0.43 ± 0.01^{b}	0.11 ± 0.01^{b}
NFT VERTICAL C. Tolstoi	1.38 ± 0.02^{c}	15.40 ± 0.72^{bc}	1.15 ± 0.03^{d}	0.64 ± 0.01^{d}	0.11 ± 0.01^{b}
SOIL CONTROL Tolstoi	0.71 ± 0.03^{a}	14.63 ± 0.42^{ab}	0.78 ± 0.03^{b}	0.55 ± 0.01^{c}	0.11 ± 0.01^{b}
NFT VERTICAL C. R. yellow	1.36 ± 0.02^{c}	16.35 ± 0.97^{c}	0.91 ± 0.02^{c}	0.40 ± 0.02^{a}	0.10 ± 0.01^{ab}
SOIL CONTROL R. yellow	1.28 ± 0.01^{b}	13.63 ± 0.74^{ab}	0.61 ± 0.02^{a}	0.38 ± 0.01^{a}	0.09 ± 0.01^{a}

Data were shown in mean ± standard deviation (n = 9)

The values with the different letter within same column are statistically significant by Duncan's test at $p \leq 0.05$

soil condition showed least Zn concentration for all the varieties under observation. *Roma* and *Tolstoi* showed maximum concentration of Mn in NFT system while significantly lower Mn content was recorded in R. yellow variety both in hydroponic and soil condition. NFT system with *Roma* exhibited the highest Cu concentration (0.12 ± 0.01 mg) which was similar with NFT system with *Tolsto*i and soil cultivation with both *Roma* and *Tolstoi* (0.11 ± 0.01 mg). The lowest Cu concentration (0.09 ± 0.01 mg) was recorded in soil cultivation with *R. yellow*.

From this study it was observed that in NFT system, mineral content was significantly higher due to optimum absorption of plant nutrients. Our results were supported by Sainju et al. (2003) and Cardoso et al. (2018). They reported that in hydroponics system especially in circulated NFT system, plant nutrients supply was in optimum which may have helped in increasing nutrients concentration in plant. The capacity of hydroponic nutrient solution to support plant growth in hydroponic system is due to its multi-nutrient characteristic, which improved the chlorophyll content and photosynthetic rate of tomato plants. This could be associated with the high levels of micronutrients content such as Zn, Fe, Cu, Mn and Mg. Significant variations in mineral nutrient content was observed among the studied varieties which implies that genetic factors are also responsible for mineral absorption beside environmental and agronomic factors. Our results were more or less similar to those of Kaaya et al. (2002) who analysed the mineral content such as Zn, Cu, Mn, Mg and Fe in five different varieties of tomato and found significant variations among the varieties. Tariq et al. (2020) analysed mineral nutrient of 28 genotypes of organically grown tomato and found that environmental conditions induced variation in the mineral status of tomato genotypes.

Conclusion

In this study tomato varieties grown by hydroponics especially by vertical NFT system showed higher yield and better quality, rapid harvest and higher nutrient content with respect to plant mineral nutrients concentration. NFT hydroponics system saved about 70–80% water with maximum tomato yield compared to field condition. Overall, NFT system of hydroponics provides efficient nutrient management and leading to increase in production with minimum water consumption by crops. Hydroponics offers an innovative technological solution for sustainable agriculture, preserving soil resources whilst building food self-sufficiency in areas with limited available agricultural land, such as urban areas and arid regions. In this way, hydroponics can be used to produce food with lower use of resources and build equitable, self-sufficient food systems worldwide.

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Declarations

Conflict of interest Authors have no conflict of interest.

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